

MULTI-OBJECTIVE OPTIMIZATION OF CUTTING PARAMETERS IN HARD TURNING PROCESS USING GENETIC ALGORITHM (GA) & ARTIFICIAL NEURAL NETWORK(ANN)

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ABSTRACT

Manufacturing industry today faces the challenge of having to develop high quality products faster and economically than ever before. Therefore optimization is seen as an innovative technique under certain premises. Optimization in turning means determination of the optimal set of machining parameters to satisfy the objectives within the operational constraints. Predictive modeling is essential for understanding and optimization of the machining process. The aim of this study is to develop an integrated model to optimize the cutting parameters that are affecting the quality of surface produced in hard turning process on EN 353 metal. Three input parameters were selected for study: cutting speed, feed & depth of cut to determine the optimal cutting parameters required for minimum surface roughness, power consumption and for maximum metal removal rate. Mathematical equations are formulated as objective functions, to determine the optimal cutting parameters so that minimization of surface roughness/power consumption and maximization of metal removal rate are evaluated by using MATLAB software. Genetic Algorithm(GA) supported with tested ANN is utilized to determine the best combinations of cutting parameters through optimization process. Artificial Neural Network (ANN) on back propagation learning with hidden neurons is used to validate the model. The trained machined data was tested and the results show that the model has the ability to solve many problems including predicting, modeling and measuring experimental knowledge under dry environment. From these results, it can be easily realized that the developed study is reliable and suitable for solving the other parameters encountered in metal cutting operations as the same as surface roughness.

KEYWORDS: Artificial Neural Network (ANN), Genetic Algorithm(GA), Regression Analysis, CVD

INTRODUCTION

Manufacturing of goods involves the machining of parts or components with the cutting tools set or loaded on the machine tools. The selection of suitable material and the suitable cutting tool combination plays greater role in Production / Manufacturing parts or components in industry. The turning process parameter optimization is highly constrained and non – linear. ANNs have been trained based on back propagation(BP) learning algorithm and tested to control the performance of trained ANN model. By adapting the tested ANN model with powerful GA optimization was applied to achieve best combination of cutting parameters. The performance of ANN is carried out with experimental data of CVD on EN 353. The simulation is carried out for 3 parameters over surface roughness, MRR and power consumption. The input-output dataset consisting of 27 patterns was divided randomly in two categories: training dataset consist of 75% of the data and test dataset which consist 25 % of the data. There are 20 training patterns considered for ANN modeling of surface roughness and material removal rate. After the training, the weights are frozen and the model is tested for validation. In this work, the network is validated in terms of agreement with experimental results.

LITERATURE SURVEY

A detail literature survey is carried out as follows: C. Natrajan et.al [1], found suitable optimization method which can find optimum values of cutting parameters for minimizing surface roughness. The turning process parameter optimization is highly constrained and nonlinear. To predict the surface roughness, an artificial neural networks (ANN) model was designed through back propagation network using MATLAB 7 software for the data obtained. S.M.Ali, and N.R. Dhar [2], Tool wear and surface roughness prediction plays a significant role in machining industry for proper planning and control of machining parameters and optimization of cutting conditions. He deals with developing an ANN model as a function of cutting parameters in turning steel under minimum quality lubrication(MQL).A feed forward backward propagation network with 25 hidden neurons has been selected as the optimum network. M. Nalbant et.al [3], the Taguchi method is used to find the optimal cutting parameters for surface roughness in turning. The orthogonal array, the signal to noise ratio, and analysis of variance are employed to study the performance characteristics of AISI 1030 steel bars using Tin coated tools.

Three cutting parameters namely insert radius, feed rate and depth of cut are optimized with considerations of surface roughness. Adeel H.Suhail et.al [4] the focus of the present experimental study is to optimize the cutting parameters using two performance measures, work piece surface temperature and surface roughness. Optimal cutting parameters for each performance measure were obtained employing Taguchi techniques. The orthogonal array, signal to noise ratio and analysis of variance were employed to study the performance characteristics of the turning operations. G. Krishna Mohana Rao et.al [5], Development of hybrid model and optimization of metal removal rate in electric discharge machining using ANN and GA, in this study a multiceptron neural network models were developed using Neuro solutions package. Genetic algorithm concept is used to optimize the weighting factors of the network. It is observed that the developed model is within the limits of the agreeable error when experimental and network model results are compared for all performance measures considered. Azlaan Mohd Zain et.al [6] Application of GA to optimize cutting conditions for minimizing surface roughness in end milling machining process, this study attempts the applications of GA to find the optimal solution of the cutting conditions for giving the minimum value of surface roughness.

This means the GA technique has decreased the minimum surface roughness value of the experimental sample data, regression modeling and response surface methodology technique about 27%, 26%, 50% respectively. Tugrul Ozel and Yigit Carpat [7] used a neural network modeling approach to predict surface roughness and tool wear in turning operation. The factors considered were work piece propertiestool material tool geometry and cutting conditions in it a prediction system was developed which was capable of accurate surface roughness and tool wear prediction for the range it has been trained. Based on the literature review, the present work is carried out by implementing DOE, Genetic Algorithm(GA) and Artificial neural networks (ANN). The multi-objective optimization quantitatively determines the relationship between Surface Roughness (Ra), Material Removal Rate (MRR), and Power Consumption (PC), with optimal combination of input machining parameters.

EXPERIMENTAL PROCEDURE

Every machine tool has certain minimum cutting speed available in it. Also, certain minimum speed, has to be maintained such as, in the case of coated carbide tools to avoid the failure of cutting tools due to built up edge (BUE) formation. Out of these two, higher speed is taken as minimum cutting speed. Feed rates are taken from the available data on the machine, and as recommended by tool manufacturer in the catalogue. The range of depth of cut is considered to lie in between 0.1 to 0.25mm to compensate both finish and rough machining. The cutting parameters were set as 3 levels of

spindle speeds ('S') (740,580,450 rpm),3 levels of feed rate ('f') 0.05,0.07,0.09 mm/min and 3 levels of depth of cut ('D') 0.25,0.2,0.1 mm, 27 experiments with 3 runs.

Chemical Composition of the Work Piece Material: EN353

Table 1

Element	C	Si	Mn	S	P	Cr	Mo	Ni
Composition (Weight %)	0.17	0.19	0.6	0.04	0.04	0.92	0.1	1.03

Composition of Selected CVD Coated Tool

Table 2

Type	Grade	Density (kg/m ³)	Hardness	Fracture Toughness
CVD	CA 5515	14.5	1550	12GPa

Surface Roughness Measurements

The surface roughness is measured after end of each cut by using Mitutoyo Surface Roughness Tester (SJ-201 P) Stylus type. As the surface of the turned work piece is cylindrical in shape, surface roughness is measured on four diametrical points and the average of them was taken as surface roughness of that operation.

OBJECTIVE FUNCTIONS FOR EN 353 ON CVD TOOL

Formulation of objective function for surface roughness (Ra), material removal rate (MRR), Power consumption (PC)

Min Ra (v, f, d)

$$\text{Minimizing } Ra = 0.07V^{0.218}F^{-0.23}D^{0.233} \quad (1)$$

$$\text{Maximising } MRR = -11.0V^{1.76}F^{0.110}D^{0.586} \quad (2)$$

$$\text{Minimisation } PC = -10.4V^{1.79}F^{-0.409}D^{0.175} \quad (3)$$

Constraints

$$V_{\min} \leq V \leq V_{\max}, 450 \leq V \leq 740 \quad (4)$$

$$f_{\min} \leq f \leq f_{\max}, 0.05 \leq f \leq 0.09 \quad (5)$$

$$d_{\min} \leq d \leq d_{\max}, 0.10 \leq d \leq 0.25 \quad (6)$$

RESULTS AND DISCUSSIONS

Table 3: Optimal Cutting Conditions and Response Values for Different Weighting Factors

S.No	Weights			Optimal cutting Condition Levels			GA		
	W1	W2	W3	(V)	(F)	(D)	Ra	MRR	PC
1	0.078	0.374	0.548	738.4719	0.089967	0.249919	3.257945	0.635459	8.710652
2	0.374	0.548	0.078	732.5836	0.089956	0.249884	3.252147	0.626509	8.586929
3	0.548	0.078	0.374	739.9953	0.08997	0.248956	3.255924	0.63633	8.736813
4	0.374	0.078	0.548	736.5867	0.089898	0.25	3.256481	0.632674	8.674103
5	0.078	0.548	0.374	705.5999	0.09	0.249991	3.225998	0.586643	8.028043
6	0.548	0.374	0.078	720.7046	0.09	0.249965	3.240834	0.608888	8.338092

Table 4: GA versus ANN Surface roughness (Ra) Values

S. No	Weights			Optimal Cutting Conditions			GA	ANN
	W1	W2	W3	(V)	(F)	(D)		
1	0.078	0.374	0.548	738.4719	0.089967	0.249919	3.257945	3.2983
2	0.374	0.548	0.078	732.5836	0.089956	0.249884	3.252147	3.2645
3	0.548	0.078	0.374	739.9953	0.08997	0.248956	3.255924	3.2645
4	0.374	0.078	0.548	736.5867	0.089898	0.25	3.256481	3.2930
5	0.078	0.548	0.374	705.5999	0.09	0.249991	3.225998	3.1235
6	0.548	0.374	0.078	720.7046	0.09	0.249965	3.240834	3.2022

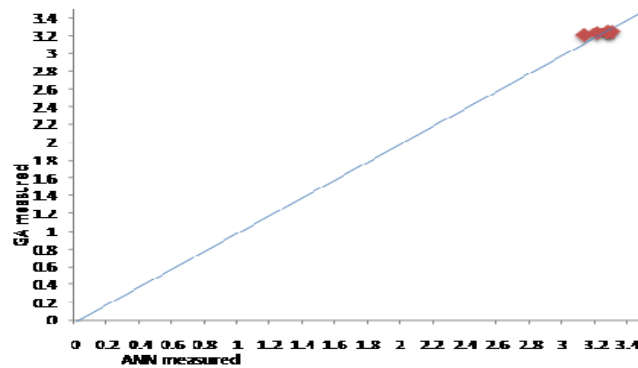


Figure 1: GA versus ANN Surface Roughness (Ra) Values

Table 5: GA versus ANN Material Removal Rate (MRR) Values

S. No	Weights			Optimal Cutting Conditions			GA	ANN
	W1	W2	W3	(V)	(F)	(D)		
1	0.078	0.374	0.548	738.4719	0.089967	0.249919	0.635459	0.6243
2	0.374	0.548	0.078	732.5836	0.089956	0.249884	0.626509	0.6026
3	0.548	0.078	0.374	739.9953	0.08997	0.248956	0.63633	0.6253
4	0.374	0.078	0.548	736.5867	0.089898	0.25	0.632674	0.6193
5	0.078	0.548	0.374	705.5999	0.09	0.249991	0.586643	0.5093
6	0.548	0.374	0.078	720.7046	0.09	0.249965	0.608888	0.5589

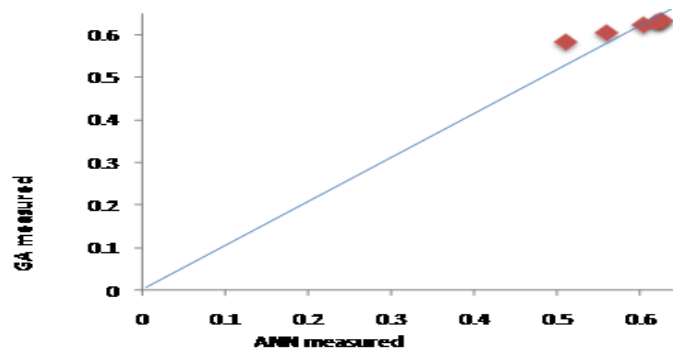


Figure 2: GA versus ANN Material Removal Rate

Table 6: GA versus ANN Power Consumed (PC) Values

S.No	Weights			Optimal Cutting Conditions			GA	ANN
	W1	W2	W3	(V)	(F)	(D)		
1	0.078	0.374	0.548	738.4719	0.089967	0.249919	8.710652	9.6754
2	0.374	0.548	0.078	732.5836	0.089956	0.249884	8.586929	8.7425
3	0.548	0.078	0.374	739.9953	0.08997	0.248956	8.736813	8.8673
4	0.374	0.078	0.548	736.5867	0.089898	0.25	8.674103	8.6389
5	0.078	0.548	0.374	705.5999	0.09	0.249991	8.028043	10.8547
6	0.548	0.374	0.078	720.7046	0.09	0.249965	8.338092	9.7984

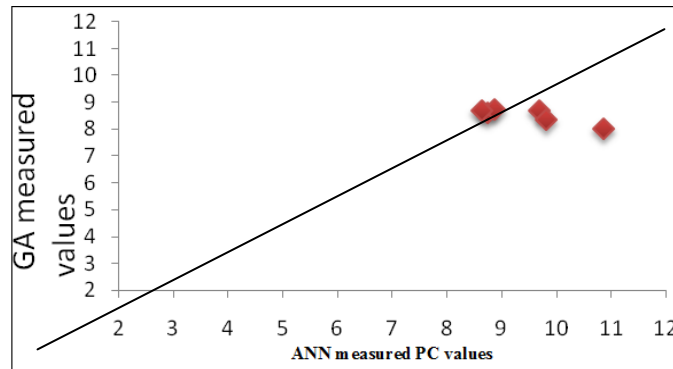


Figure 3: GA versus ANN Power Consumed

- From the results of GA on CVD shows that for the weights $W1 = 7.8\%$; $W2 = 37.4\%$; $W3 = 54.8\%$; i.e. Minimization of power consumption is the highest priority, shows the optimum conditions of 739 RPM of speed; Feed 0.09mm/min and 0.25mm of Depth of cut for which the predicted surface roughness is $3.257\mu\text{m}$; $0.6354\text{ mm}^3/\text{min}$ of MRR; and 8.71W of power consumption. The optimum values of GA results for this level is simulated in ANN, shows an approximate deviation of 1.2%, 1.7% and 11.0% from the actual GA value for Ra, MRR and PC.
- From the another set of results of GA on CVD shows that for the weights $W1 = 37.4\%$; $W2 = 54.8\%$; $W3 = 7.8\%$; i.e. Maximization of MRR is the highest priority, shows the optimum conditions of 733 RPM of speed; Feed 0.09mm/min and 0.25mm of Depth of cut for which the predicted surface roughness is $3.252\mu\text{m}$; $0.6265\text{ mm}^3/\text{min}$ of MRR; and 8.586W of power consumption. The optimum values of GA results for this level is simulated in ANN, shows an approximate deviation of 0.4%, 3.81% and 1.82% from the actual GA value of Ra, MRR and PC.
- From the another set of results of GA on CVD shows that for the weights $W1 = 54.8\%$; $W2 = 7.8\%$; $W3 = 37.4\%$; i.e. Minimization of surface roughness is the highest priority, shows the optimum conditions of 740 RPM of speed; Feed 0.09 mm/min and 0.25mm of Depth of cut for which the predicted surface roughness is $3.255\mu\text{m}$; $0.6363\text{ mm}^3/\text{min}$ of MRR; and 8.73W of power consumption. The optimum values of GA results for this level is simulated in ANN, shows an approximate deviation of 0.3%, 1.7% and 1.5% from the actual GA value of Ra, MRR and PC. The large deviation of about 30% in PC is observed for other set of data. And also similar results are observed and the results of GA and ANN are in acceptable ranges which are presented graphically.
- Power consumption is observed to be deviating for the following significant reasons
 - Fluctuations in supply of voltage
 - Friction between tool and work-piece.
 - Variation in cutting forces
 - Uncontrollable factors beyond operators control.

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